Space Weather Technical Forecast

Issued on Friday, 29 December 2023 at 01:23 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Risk of G1/Minor Storm or perhaps G2/Moderate Storm from CMEs on 29 Dec. Slight chance of R1/Minor Radio Blackouts. Slight chance of Active fluence later in the period.

Analysis of Space Weather Activity over past 24 hours
Solar Activity: Solar activity has been Low, with only minor C-class flaring observed, may of these towards the end of the 24 hour period. There are seven active regions on the visible disc, with many of these stable. AR3535 has shown some development, with a weak delta configuration evident in the trailer portion of the region. AR3529, a mature region in the southwest appears to be stable as it rotates towards the western limb. All the remaining regions appear weak or benign, with limited evolution. Two CMEs have been observed from the northeast and southeast of the solar disc, but these have been assessed initially as not being Earth-directed. A more comprehensive assessment will be made once further imagery becomes available.

Solar Wind / Geomagnetic Activity: Solar wind speeds initially averaged 450 km/s, but have averaged 420 km/s following a CME arrival at 28/2252 UTC. Density rose from an average value to reach 11 ppcc on an upward trend. Total magnetic field strength, IMF, was generally weak, but increased to a peak of 8nT following the CME arrival, but has since started to decline. The north-south component, Bz, has varied weakly throughout. Phi angle has been predominantly positive (away from the Sun). Geomagnetic activity was Quiet through the period.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux started slightly elevated (but below S1 level), declining back to background. GOES16 high energy (greater than 2MeV) electron flux varied between background and moderate levels. The 24-hour fluence was below Active throughout on a predominantly flat trend. The 29/0000 UTC observation was 1.11e7 integrated pfu.

Four-Day Space Weather Forecast Summary
Solar Activity: Low activity is likely to continue, with a slight chance of Moderate activity.

Solar Wind / Geomagnetic Activity: One of two potential CME arrivals (or a combination of the two) is currently affecting the Earth, with effects likely to continue through much of 29 Dec and perhaps into 30 Dec. Otherwise, a high speed stream from coronal hole 86 is forecast to connect with Earth either late on 31 Dec or on 01 Jan, giving speeds of 400-500 km/s. Geomagnetic activity will start Quiet with a chance of Active or G1/Minor Storm intervals and a slight chance of G2/Moderate Storm intervals. Activity is then expected to decline to Quiet to Unsettled levels through 30 Dec, but then a risk of further active to G1/Minor Storm intervals late on 31 Dec or on 01 Jan due to the connection with the high speed stream.

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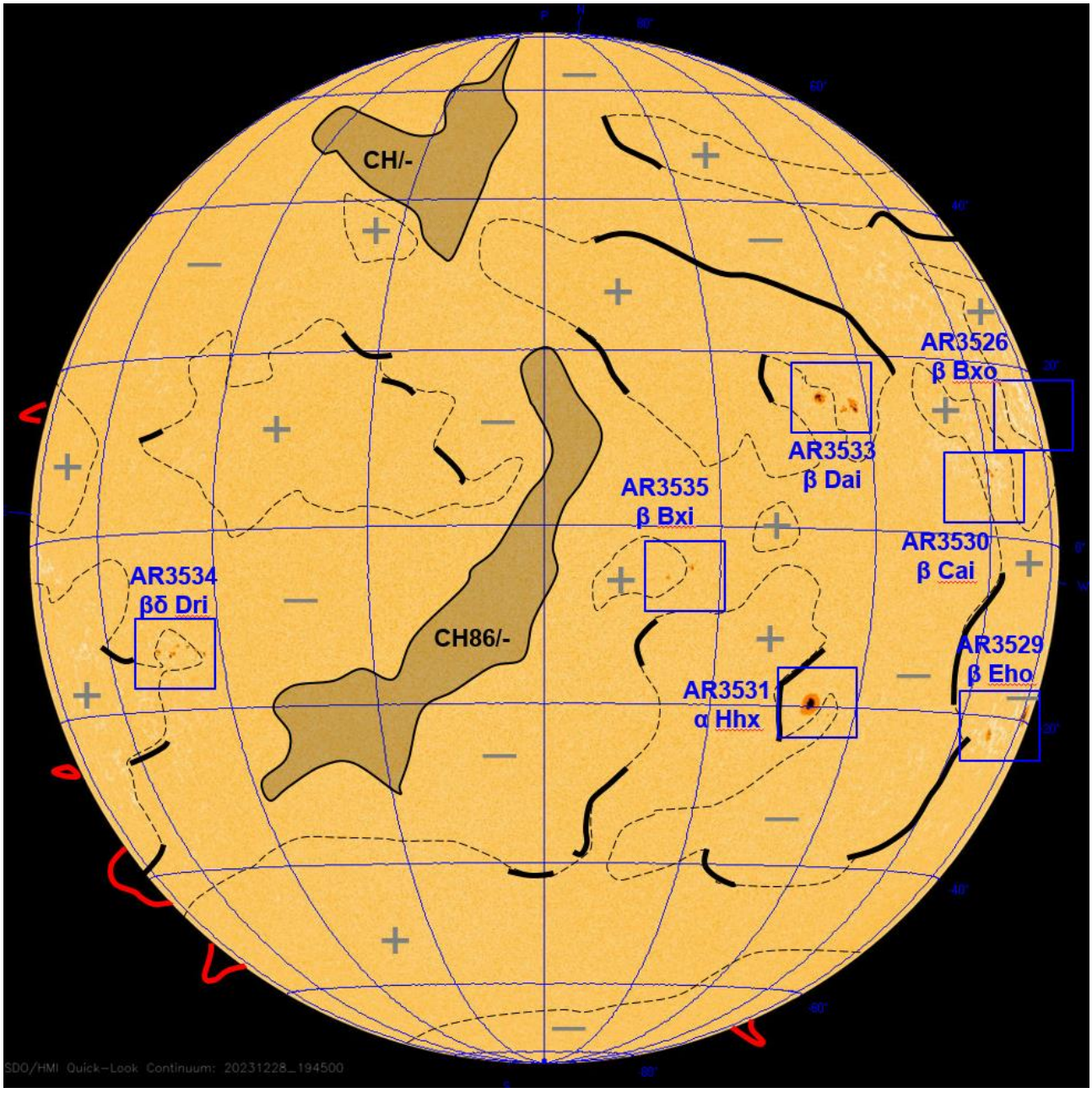
Energetic Particles / Solar Radiation: GOES16 high energy proton flux is at background and likely to persist at this level. There is a very with a very slight chance of reaching S1 given any further notable flares from AR3529 or other regions on the disc. GOES16 high energy electron flux is likely to be suppressed in the near term with CME arrivals, but may rise on 30 Dec as CME effects decline and then again on 31 Dec and 01 Jan due to the high speed stream connection. A rise towards the end of the period towards the Active threshold is possible, but with a low risk of reaching the threshold.

Figure 1. Solar Analysis Valid 28/2000 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

A series of CMEs were observed during 24 and 25 Dec, with three forecast to have a potential Earth-directed component. Although one is now assessed as already missing, two were due to arrive either late on 28 or early on 29 Dec. One of these arrivals has been observed at L1, which will be assessed once more data becomes available to determine if it can be attributed to a specific eruption, or whether it may be a combination of two CMEs.

Including the effects of the CME, solar wind speeds have been averaging around 400-450 km/s in a slightly elevated solar wind environment. The Earth may connect with the high speed stream from coronal hole 86 either late on 31 December or early on 01 January. This is a large, distinct returning feature with a high confidence of a connection, which produced speeds of around 500km/s on the last rotation. It is slightly smaller this time around, with speeds estimated to reach 400-500 km/s.

Starting Quiet, with a chance of Active or G1/Minor storms and a slight chance of G2/Moderate storms early on 29 Dec due to the possible impact of the CME arrival, with effects possibly continuing into 30 Dec, before subsiding. The coronal hole high speed connection with a possible preceding CIR (co-rotating interaction region) could give a slight chance of G1/Minor storms later on 31 Dec and into 01 Jan although geomagnetic responses are more muted close to the solstice.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	40	10	10	10
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
24/2224	Partial	Filament	SW	572 km/s	28/0600 UTC	Low confidence glancing blow
24/1442	Full	Filament	NE Centre	538 km/s	28/1400 UTC	Possible observed arrival late 28 Dec

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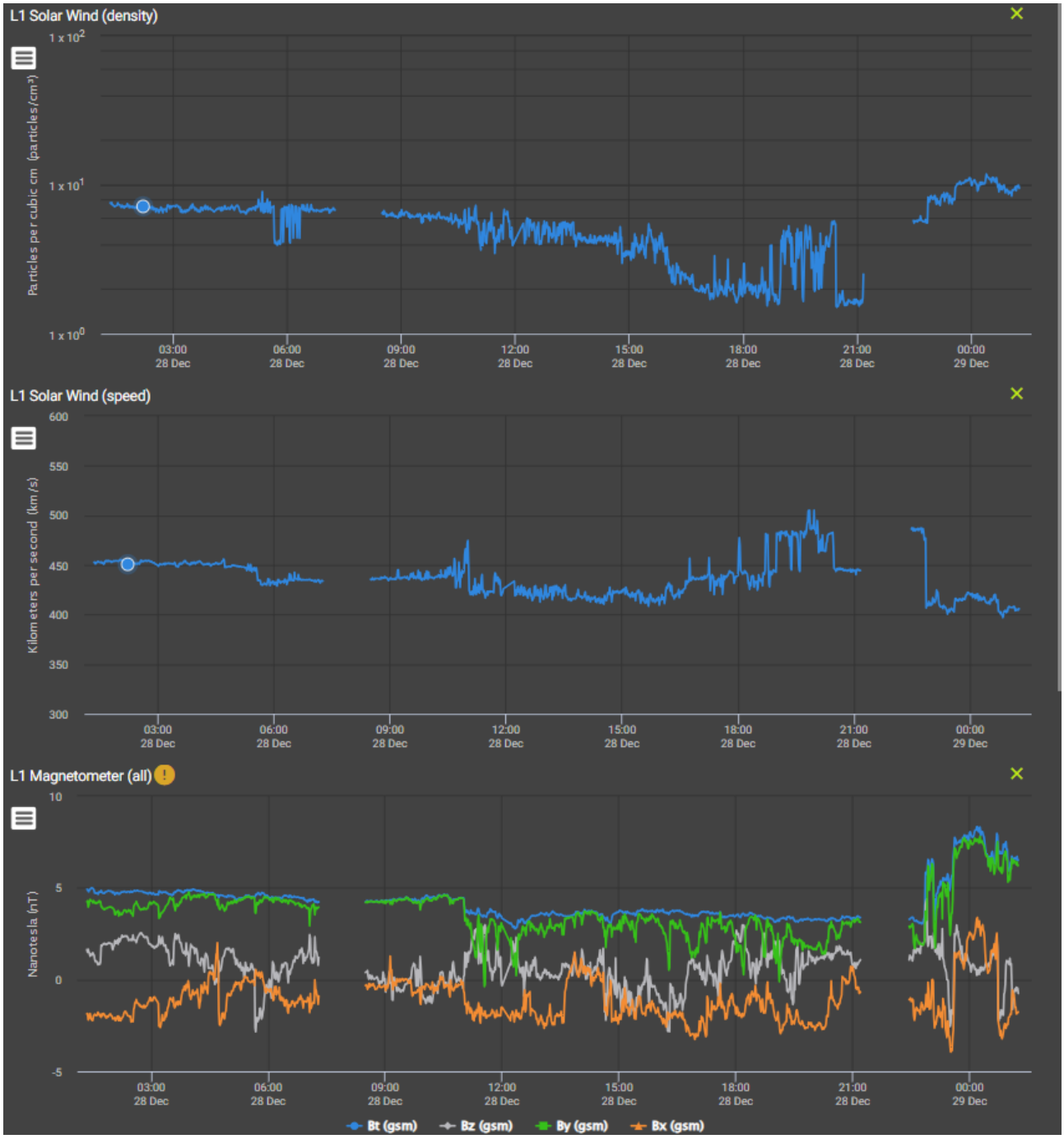
Figure 2: L1 DSCOVR observations, showing signs of the weak CME arrival including increasing density and strengthening IMF.



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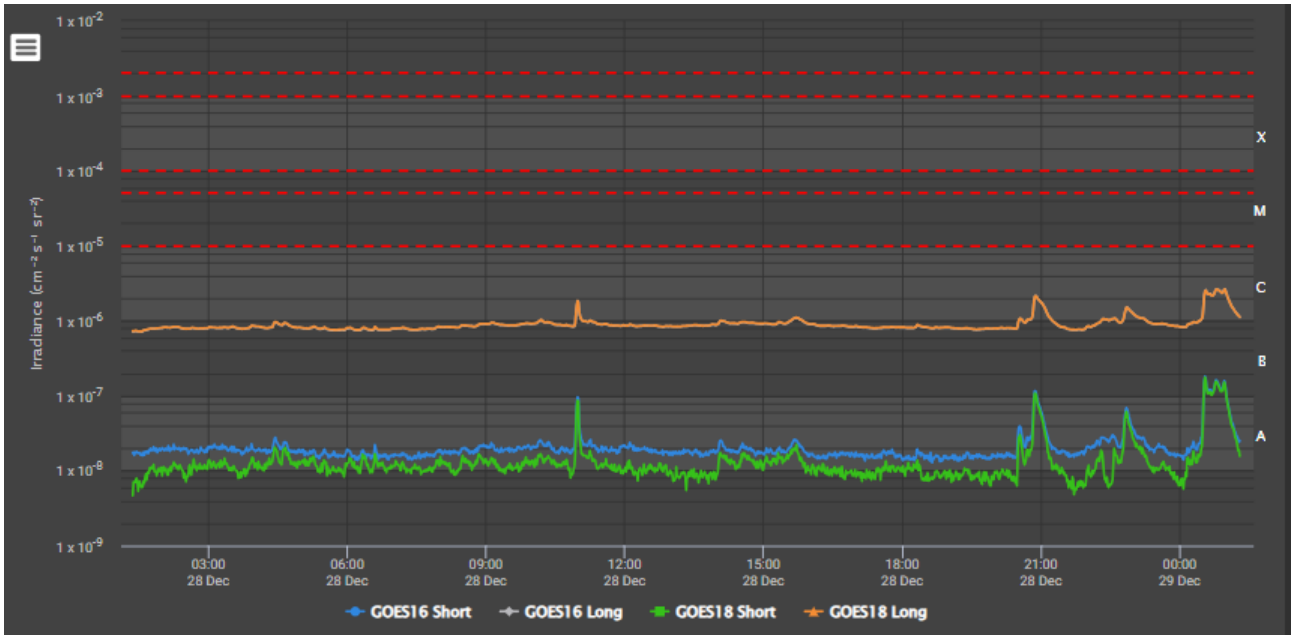
Radio Blackouts - X-Ray Flares:
There are seven sunspot regions on the visible disc, with limited evolution and muted solar activity. AR3535 appears to have evolved a very weak delta spot but this is already starting to fade. The largest region on the disc is the mature AR3529 which appears inactive and a low risk for flare activity. The remaining regions all appear stable or benign, with no significant regions forecast to rotate across the limb from the far side of the Sun.

Solar activity is forecast to be mainly Low, with a slight chance of Moderate activity. This activity is then forecast to reduce slightly once AR3529 rotates across the western limb.

X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	R1-R2 M Class	No	20	20	15	15
Very Active	R3 to R5 X Class	No	1	1	1	1

Figure 3: GOES 16 X-ray flux



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Solar Radiation Storms - (High Energy Protons):

GOES16 high energy (greater than 10MeV) proton flux started slightly above background but gradually return to background through the last 24 hours.

There is a very slight chance of proton enhancement if any further significantly energetic flare activity or Earth-directed CMEs were to be observed

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	5	5	5
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) has varied between background and moderate levels. This may drop to background levels on 29 Dec due to the arrival of CME which could initially displace electrons from the radiation belts, due to the any geomagnetic activity generated by the initial impact before electron counts then build as electrons settle back into the radiation belt. Any subsequent increase in flux may then be modest, with a more sustained increase possible due to the high speed stream from coronal hole 86 during 01 Jan, following an initial high speed stream connection on 31 Dec.

Electron fluence is likely to show a steady or shallow downward trend through the next two days due to the opposing effects of the CME arrival followed by possible input into the radiation belts. A more sustained rise is then possible during 01 Jan in response to the increasing flux. Fluence levels may approach, but are unlikely to reach the Active (1e8 integrated pfu) threshold by the end of the period. There is however some uncertainty in the forecast due to the unknown effects of the CME arrival.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	1	10	10
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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